

Kelp, Carbon and a Living Sea

A Hastings Kelp Project briefing · Oct 24, 2026 · @Chris

In short

Kelp forests take carbon out of the atmosphere, and some of it is locked away for a century or more. How much, from any particular stretch of coast, is still one of the most uncertain numbers in ocean science.

- **What we know:** UK kelp forests shed about 3 tonnes of carbon per hectare a year, and almost all of it drifts away from the forest.
- **What we don't know:** how much of that is stored for the long term. Published estimates suggest roughly 1% to 12%.
- **What it could mean here:** 100 hectares of restored kelp off Hastings could store an estimated 11 to 132 tonnes of CO₂ a year.

To count it honestly, BlueTerra Ltd, a sister company founded by HKP's director, is developing a conservative carbon accounting framework. It is a work in progress, not yet validated on a real site.

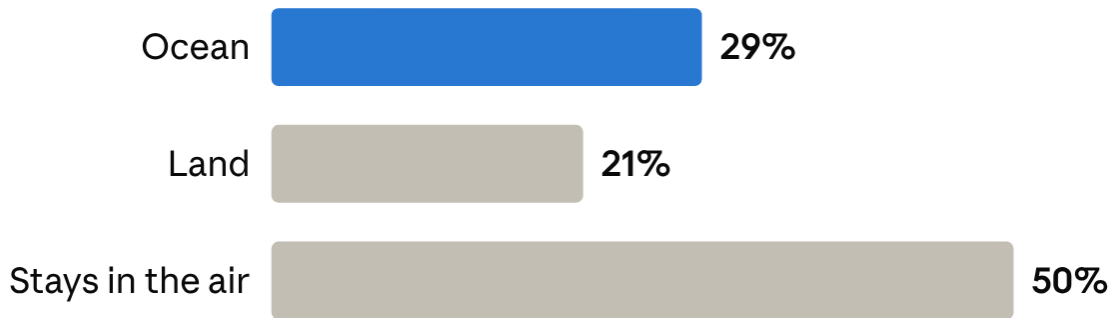
The hope is real: every hectare of kelp restored adds to a natural carbon sink. Our job is to measure it honestly.

The ocean and carbon

The ocean is the planet's biggest natural carbon sink. Over the past decade it absorbed about 29% of the CO₂ people emitted, more than all the world's land ([Global Carbon Budget 2025](#)). Most of that is chemistry and plankton in open water, not coastal plants. The price is paid in acidity: more dissolved CO₂ makes seawater more acidic, which stresses shell-builders like mussels and oysters.

The ocean absorbs 29% of the CO₂ people emit

Where human CO₂ emissions went, past decade average



Global Carbon Budget 2025 (Friedlingstein et al.), 2015–2024 averages; 'stays in the air' is the approximate remainder

"Blue carbon" is the slice of that story we can influence locally: carbon captured by coastal and marine ecosystems ([IUCN](#)). Three habitats are formally recognised:

- **Saltmarsh** and **seagrass** trap carbon in their own muddy sediments, sometimes for thousands of years.
- **Mangroves** do the same in the tropics.

Kelp was left off that list for a simple reason: it grows on rock, so it does not bury carbon where it stands. Its carbon has to travel somewhere else first. That journey is what the last few years of research have been working out.

The IUCN makes one point worth holding on to: a degraded ocean loses its capacity to act as a carbon sink at all. Healthy ecosystems and a working carbon cycle are the same project.

How a kelp forest lives

A kelp forest is less a store cupboard than a factory with a fast turnover. Its carbon story follows the rhythm of its year.

Growth runs on the seasons. Sugar kelp, the species HKP grows, puts on most of its length from late winter to spring, typically about 1.1 cm a day and occasionally almost 5 cm. Growth slows from June and may stop in late summer, probably because nitrate runs short ([MarLIN](#)). In the British Isles, it releases spores mostly in autumn and winter.

Season	What sugar kelp does	What it means for carbon
Late winter to spring	Fastest growth	Most carbon drawn down

Season	What sugar kelp does	What it means for carbon
Summer	Growth slows or stops; blade tips wear away	Carbon leaves as fragments and dissolved carbon
Autumn to winter	Spores released; storms tear plants loose	Pulses of detritus leave the forest

It wears away from the tip. Kelp grows from the base of the blade and erodes from the tip, like a slow conveyor belt. In Norwegian sugar kelp farms, between 40% and 100% of plants were eroding at their tips at any one time ([Fieler et al. 2021](#)). That steady wear is one of the main routes by which kelp carbon leaves the forest.

It changes the water around it. By day, kelp draws CO₂ out of the water and releases oxygen, which raises the local pH. A review of studies found this effect was strongest in dense forests in calm, shallow water, and varied over time ([Strain et al. 2023](#)). Under Greenland's 24-hour summer daylight, kelp took up enough CO₂ to offset ocean acidification locally ([ScienceNordic](#)). It is local, temporary relief rather than a cure, but it matters to the shell-building animals that live among the kelp.

How kelp moves carbon

Kelp stores very little carbon in itself for long. Its climate value comes from what it sheds. A forest is fast-growing and leaky: old blades are shed each spring, storms rip plants loose, and tissue erodes all year ([MarLIN](#)). In one Norwegian forest, detached old blades made up more than half of all kelp detritus ([Pedersen et al. 2020](#)).

That detritus then takes one of four roads:

1. **Eaten locally.** Grazers, crabs and worms consume it, and most of the carbon is breathed back out. This feeds the food web, which is no bad thing.
2. **Buried nearby.** Some settles into coastal sediments. This store is real but can be disturbed by trawling and dredging.
3. **Exported to deep water.** Fragments sink and are carried by bottom currents off the continental shelf. Below about 200 m, carbon can stay out of contact with the atmosphere for a century or more.
4. **Dissolved.** Kelp leaks dissolved organic carbon, a small part of which resists breakdown for long periods. This pathway is the least well measured.

The headline global study, published in *Nature Geoscience* in 2024, estimated that about 15% of seaweed forest production crosses the continental shelf. It put the carbon locked away for at least 100 years at 4 to 44 million tonnes a year ([Pessarrodona et al. 2024](#)). That

tenfold range is the honest measure of how uncertain this still is. The same work found export is highest near canyons, fjords and narrow shelves close to the deep sea ([Utrecht University](#)).

Geography matters enormously. Off southern Australia, models show dense seabed currents carrying 17 to 29% of kelp detritus past the shelf edge, but almost none when those currents don't run ([Scientific Reports, 2024](#)).

Following the trail

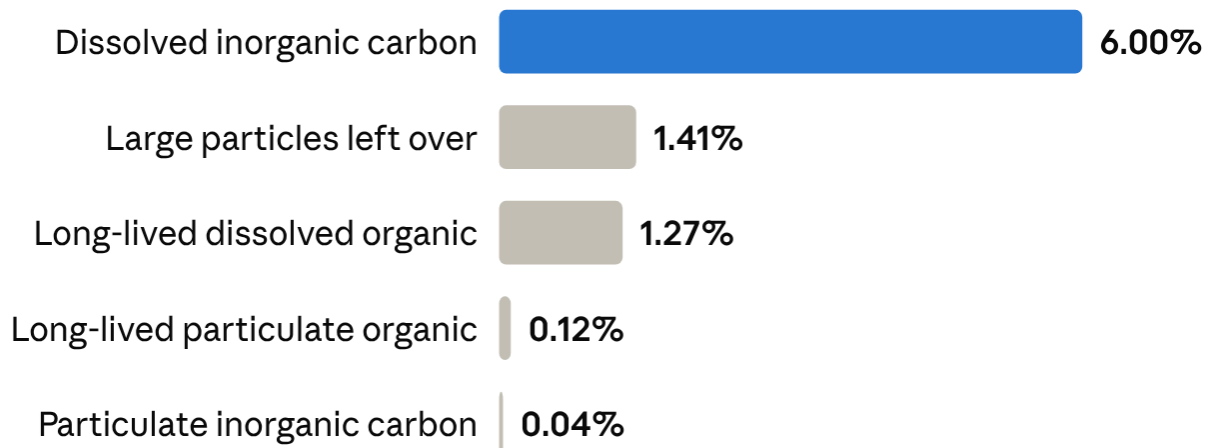
Because kelp carbon travels, researchers have had to become detectives. Several independent lines of evidence now point the same way.

- **Kelp rots slowly.** In UK forests, detached kelp took more than four months to decompose, long enough to travel a long way ([Smale et al. 2021](#)). Drifting fragments can even keep photosynthesising for several months ([de Bettignies et al.](#)).
- **It sinks, and grazers help it travel.** Kelp detritus sinks faster than equivalent phytoplankton. When sea urchins eat kelp and turn it into faecal pellets, its potential to disperse rises 10- to 100-fold ([Scientific Reports, 2018](#)).
- **Its DNA turns up far from shore.** Global ocean expeditions found seaweed DNA up to 5,000 km from the coast. The signal faded with depth, but about a quarter of what was at the surface was expected to reach the seafloor at 4,000 m ([Ortega et al. 2019](#)). In sediments, the amount of seaweed DNA tracks the amount of seaweed carbon, which makes DNA a practical tracer ([Ortega et al. 2020](#)).
- **It reaches coastal mud too.** A study led by Plymouth Marine Laboratory found DNA from nearby seaweeds in deep coastal sediments, with seaweed carbon stored there at an average of 8.75 g per m² a year ([Queirós et al. 2019](#)).
- **Some of it dissolves.** On a Norwegian sugar kelp farm, 12% to 29% of the carbon the kelp fixed was released as dissolved organic carbon ([SINTEF](#)). Part of that resists breakdown for a long time: in waters around one Chinese kelp farm, about 58% of the dissolved carbon extracted proved resistant in long-term tests ([Environmental Science & Technology, 2022](#)).

In a 210-day laboratory decay experiment, most kelp detritus carbon was broken down, but a small share ended up in forms stable enough to count towards long-term storage.

After 210 days of decay, about 9% stayed stable

Share of starting kelp detritus carbon in stable forms (total 8.8%)



Microbial-mediated contribution of kelp detritus to oceanic carbon sequestration, Ecological Indicators 2022; 210-day dark laboratory degradation, forms as classed by the study

Decay in the sea is messier than in a laboratory, but the pattern matches the field evidence: most kelp carbon returns to the water and air, and a small, real fraction stays.

A sink under pressure

The carbon kelp moves depends on there being kelp at all, and that is not guaranteed.

Kelp forests are changing worldwide. A global analysis of 50 years of records from 1,138 sites found kelp had declined in 38% of the regions studied, and increased in just over a quarter ([UNSW](#)). Local pressures, such as nutrients and fishing, combined with warming to drive the losses ([UWA](#)). Every lost forest is a lost carbon flux; every recovered one puts it back.

Warmth and murk are carbon problems too. Along a north-south temperature gradient, kelp forests in warmer waters took up, on average, less than a third of the carbon of those in colder waters, and released less than half as much particulate carbon ([Pessarrodona et al. 2018](#)). Across UK sites, the carbon held in kelp rose with light and fell with temperature ([Smale et al. 2016](#)). So our work on sea temperature and turbidity is carbon research as much as habitat research.

Kelp in warmer water handles far less carbon

Index: kelp forests in colder waters = 100

Carbon taken up



Carbon released as particles



Pessarrodona et al. 2018, *Laminaria hyperborea* along a NE Atlantic temperature gradient; warm-water bars show the reported upper bounds

Warmer water also rots kelp faster. A field experiment spanning 28 degrees of latitude found kelp detritus decomposed faster in warmer water, so less of it survives long enough to reach long-term sinks ([Filbee-Dexter et al. 2022](#)). The same study suggests cooler northern waters, where kelp is expected to expand, may become more important kelp carbon sinks.

Carbon on our coast

UK kelp forests shed a lot of carbon, but nobody yet knows how much of it stays locked away. The chain below shows what UK research has measured, and how much of it applies to Hastings.

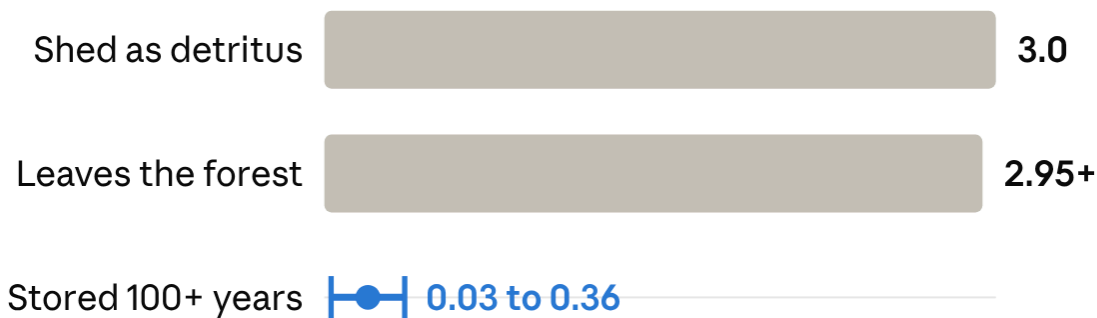
Step in the chain	What UK research has measured	What we know for Hastings
Carbon fixed and shed as detritus	About 301 g of carbon per m ² per year from <i>Laminaria hyperborea</i> forests at eight UK sites, roughly 3 tonnes per hectare (Smale et al. 2021)	Nothing yet. There is no forest to measure, and our stock is mainly sugar kelp, a different species
Detritus leaving the forest	More than 98% exported away from the forest and nearby sediments (same study)	Unknown. Depends on our tides and currents

Step in the chain	What UK research has measured	What we know for Hastings
Carbon stored for 100+ years	Not measured in UK waters. Globally about 15% of seaweed production crosses the shelf edge (Pessarrodona et al. 2024)	Probably a small fraction, given our wide, shallow shelf. A hypothesis, not a finding

The gap between the first row and the last is the whole honest story. A tonne of carbon shed is not a tonne stored.

Of 3 t of carbon shed per hectare, under 0.4 t stays

Tonnes of carbon per hectare per year, UK kelp forests



Shed and exported: Smale et al. 2021 (*Laminaria hyperborea*, 8 UK sites). Stored: 1–12% range derived from Pessarrodona et al. 2024, applied to the shed figure

The seabed itself is a carbon store. Surface sediments in UK waters hold an estimated 524 million tonnes of organic carbon ([Smeaton et al. 2021](#)). Bottom trawling stirs those sediments up and exposes that carbon to breakdown, though how much is released is still poorly quantified ([Black et al. 2022](#)).

What Hastings kelp could store

If kelp returns to our coast, a restored forest of 100 hectares could plausibly lock away somewhere between 11 and 130 tonnes of CO₂ a year. These are scenarios, not promises, and every assumption is shown so anyone can check or challenge them.

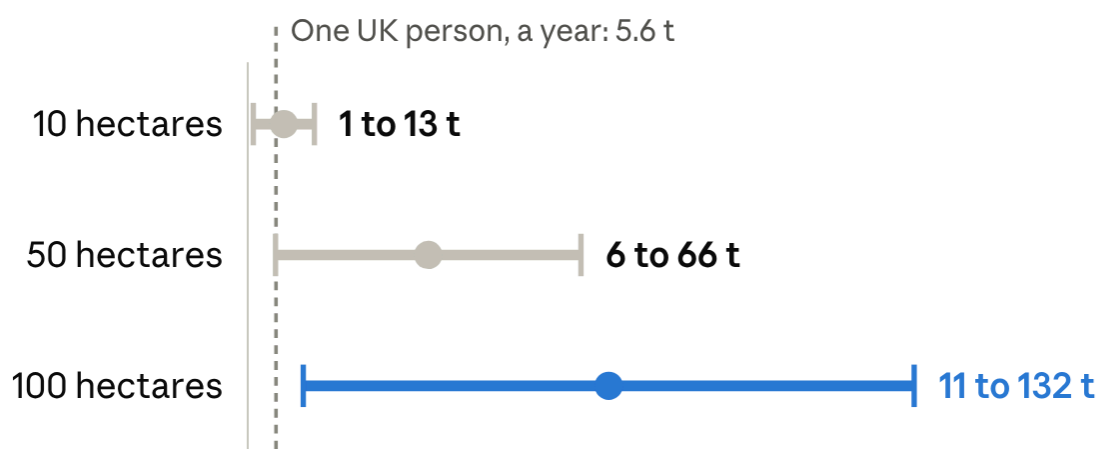
How the numbers are built

1. **What kelp sheds.** UK kelp forests shed about 3 tonnes of carbon per hectare a year as detritus ([Smale et al. 2021](#)). That figure is for *Laminaria hyperborea*. Sugar kelp, our main species, may differ.

2. **What stays locked away.** The 2024 global study implies that roughly 1% to 12% of seaweed forest production is stored for at least 100 years ([Pessarrodona et al. 2024](#)). That study left out burial on the shelf and some dissolved carbon, so the true share could be higher. Our shallow shelf may push it lower. We use the full range.
3. **Carbon to CO₂.** One tonne of carbon equals 3.67 tonnes of CO₂.
4. **Area.** We don't yet know how much seabed is suitable. The rocky ground from Rock-a-Nore to Pett Level runs for several kilometres, with outcrops seen 500–700 m offshore, so we show 10, 50 and 100 hectares. The seabed survey will tell us which is realistic.

100 ha of kelp could store 11 to 132 t of CO₂ a year

Tonnes of CO₂ stored a year, low to high scenario



HKP scenarios: 3.01 t C/ha/yr shed (Smale et al. 2021) × 1–12% stored (from Pessarrodona et al. 2024) × 3.67; UK per-person emissions from Our World in Data, 2024

Restored kelp	CO ₂ stored over 25 years (tonnes)	Equal to the yearly emissions of
10 hectares	30 to 330	up to 2 people
50 hectares	140 to 1,650	1 to 12 people
100 hectares	280 to 3,300	2 to 24 people

People equivalents use the UK average of 5.6 tonnes CO₂e per person in 2024 ([Our World in Data](#)).

Why that is still hopeful. On its own, a Hastings forest will not offset a town. But it adds up. Across the north-east Atlantic, *Laminaria hyperborea* forests release around 5.7 million tonnes of carbon a year as particles ([Pessarrodona et al. 2018](#)). Using the same 1–12% range, that is roughly 0.2 to 2.5 million tonnes of CO₂ locked away every year, by forests that also feed fisheries and shelter wildlife. Every restored stretch of coast adds to that, and every lost one subtracts from it.

These figures are not outputs of BlueTerra's framework (below), not measurements from our coast, and not carbon credits. They are a starting point. The first real number will come from measuring a Hastings forest once it grows.

Grown on ropes: a different route

Restoring wild kelp forests is HKP's purpose, and nothing here changes that. But kelp can also be grown on ropes, and that changes the carbon story.

- **More control.** A rope farm has a known area, known species and a harvest that can be weighed. That makes its carbon uptake far easier to measure than a wild forest's.
- **More choice over where the carbon ends up.** Harvested kelp can be turned into long-lived products. Biochar, made by heating biomass with little oxygen, is designed to hold carbon for long periods. How permanent the carbon in seaweed products really is remains poorly understood, and is an active research question ([PNNL 2023](#)).
- **More to account for.** Farms bring their own emissions from boats, processing and transport. Verified methods for counting farmed seaweed carbon are still being drafted ([Verra M0172](#)).

The first UK field measurements are sobering. A study of a 2-hectare sugar kelp farm in Cornwall concluded that expanding European kelp farming should be driven by other benefits, such as low-carbon products and jobs, rather than by expected carbon gains alone ([Canvin et al. 2024](#)).

Wild forests and rope farms do different jobs. A restored forest gives back habitat that a farm never will, while a farm can steer its carbon in ways a forest can't. Harvesting a restoration forest would undo the very thing it exists for, so HKP never will. Whether the two could one day sit side by side, on different ground and for different reasons, is a question worth keeping open. BlueTerra's framework already includes a profile for seaweed farms.

Counting it honestly

Numbers like the ones in this report are only as good as the accounting behind them. BlueTerra Ltd, a separate company founded by HKP's director, is developing a framework for marine carbon accounting built on the same principles used here: follow the carbon to where it ends up, count only what is likely to stay out of the atmosphere for a century, keep gross and net apart, and use only published, cited values.

In tests on a synthetic site, it counted about 8% of the carbon taken up as stored long term. It has not yet been run on a real site or peer reviewed, and its method details are confidential while patent protection is sought. It produces figures, not carbon credits.

Declaration of interest: Chris Williams is director of both Hastings Kelp Project CIC (not for profit) and BlueTerra Ltd (commercial). HKP's public science is run separately from BlueTerra's commercial work.

The honest limits

Kelp carbon is real, but it is not yet bankable, and confident claims to the contrary deserve a hard look.

- **It is hard to measure.** Unlike a saltmarsh, you cannot core the seabed under a kelp forest and count the carbon. You have to track detritus as it drifts, decays and settles, often far away. Researchers are now using genetic tracing in seawater and sediments to prove where kelp carbon ends up ([ARC project LP220200004](#)).
- **Scientists still debate the sums.** A 2022 paper argued seaweed ecosystems may release more CO₂ than they absorb once everything eaten in them is counted. Leading kelp researchers rebutted it in 2023, while agreeing that substantial uncertainties remain ([Filbee-Dexter et al. 2023, ICES JMS](#)).
- **Permanence is not guaranteed.** Carbon in living kelp returns to the atmosphere if the forest is lost. Only the share that reaches long-term sinks really counts.
- **There are no approved credits yet.** Verra's seaweed methodology framework (M0172) is still in draft development ([Verra](#)). A Gold Standard kelp methodology is not expected to be approved until after 2026 ([Kelp Blue](#)).

This is exactly why we are cautious. Overclaiming carbon would be greenwashing, and it would damage trust in every honest ocean project. Our position is simple: we will only ever talk about carbon in terms we can defend with evidence from our own coast.

Open questions for the forum

These are open carbon questions. Pick one, bring data, and help us answer it.

1. **Where does Hastings kelp detritus go?** Does it stay inshore, settle in local mud, or drift east up the Channel? Drift and beach-cast observations could start to answer this.
2. **How much reaches our sediments?** Sediment cores near the outplant sites, tested for kelp DNA, could show whether kelp carbon is being buried locally.
3. **How does temperature change carbon uptake?** Our experimental tanks can test how local sugar kelp grows, and fixes carbon, at today's and future sea temperatures.
4. **How much does murky water cost?** How much light reaches the seabed through the year, and how much growth, and carbon, does turbidity take away?

5. What happens to storm-cast kelp? How much kelp carbon washes ashore each year, and how quickly does it break down on the beach?

Post your ideas, data and challenges on the [HKP forum](#), or come to a Saturday open lab.

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